- BOMB DETECTORS
- ARMOURED VEHICLES
- BURGLAR ALARMS

Under attack! *But an array of technology is now leading the fight against crime.*

TECHNOLOGY V TERROR

IN THE FIGHT AGAINST CRIME today, technology plays an ever-important part. As criminals' methods become increasingly sophisticated, more advanced technology is needed to detect and combat them.

One obvious example is airport security – preventing terrorists from smuggling guns and explosives aboard aircraft. Metal detectors and X-ray machines form the first line of defence. They are used to screen passengers and their hand luggage before they board the plane. Metal detectors are electromagnets that either take the form of an archway through which the passenger walks, or a hand-held loop passed over the person's body.

X-ray 'eyes'

Any metal objects will alter the magnetic field generated by the electromagnet, and this change in 'field strength' triggers an alarm. Metal detectors can be adjusted to the level of sensitivity required.

X-ray machines are used to examine luggage that is taken on board the aircraft. Bags, cameras, and radios are put on to a conveyor belt which takes them through a scanning chamber. Because X-rays can travel through most materials, the scanner can form a picture of what is inside a bag or the housing of a piece of electrical equipment.

Identifying the contents relies on how 'transparent' the object is to the X-ray beam. The image is like a photographic negative displayed on a TV screen. A metal object such as a gun would show up clearly.

Similar systems are used to screen luggage before it goes into the aircraft's hold, but X-ray machines and metal detectors cannot trace explosives. Traditionally, searches for explosives have been

Laminated Glass

Just amazing!

SPEEDING BULLET

THE BULLET FROM A 7.62MM FN RIFLE CAN PENETRATE BRICK WALLS AND AT SHORT RANGES STILL COME OUT THE OTHER SIDE WITH ENOUGH ENERGY TO KILL.

Paul Raymonde

and of what kind.

These electronic 'bomb-sniffers' can be built into a walk-through arch or housed in a hand-held device. Highly sophisticated equipment like this can be very expensive; the TNA explosives detector at New York's John F Kennedy airport has cost around $750,000!

The threat of terrorist attacks on politicians and other VIPs is another area where technology has its uses.

Gamma/Frank Spooner Pictures

Analytical Instruments Ltd

If, for instance, you see the Prime Minister's car on TV, you might think it looks just like an ordinary car. But this is not so. While the exact details of the way in which it is 'protected' are kept secret, it is thought that the added security equipment brings its total weight to about 230kg more than the standard model.

It probably has 'run-flat' tyres, which allow the car to be driven even when they are punctured. It is likely to have a much more powerful engine than the standard model, both to cope with the extra weight and to give a good 'get-away' speed if attacked.

Equally likely is the use of armour-plating to protect the engine, the fuel and oil tanks, and the driver or passenger compartments from gun fire and explosions. The thin sheet metal used in ordinary car construction is of little use in stop-

carried out by specially trained 'sniffer' dogs.

But the Semtex explosive now favoured by terrorists has little, if any, detectable smell. To combat this, scientists have developed two different detection systems; one is based on thermal neutron analysis (TNA) and the other uses gas chromatography.

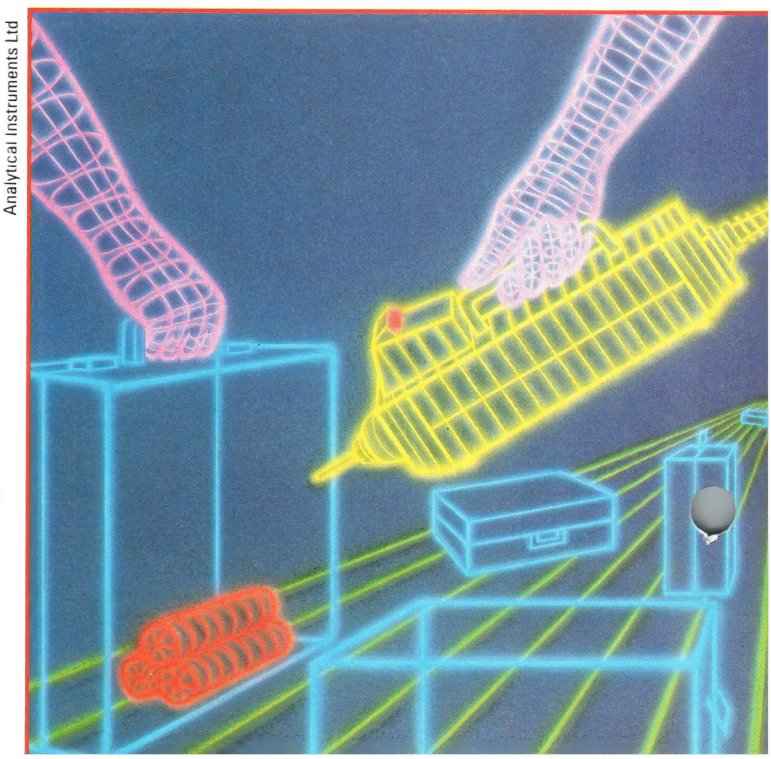
Bomb sniffers

TNA works by bombarding the luggage with a stream of neutrons and analysing the subsequent gamma rays. If the analysis reveals large amounts of nitrogen, it is almost certain to have come from plastic explosive.

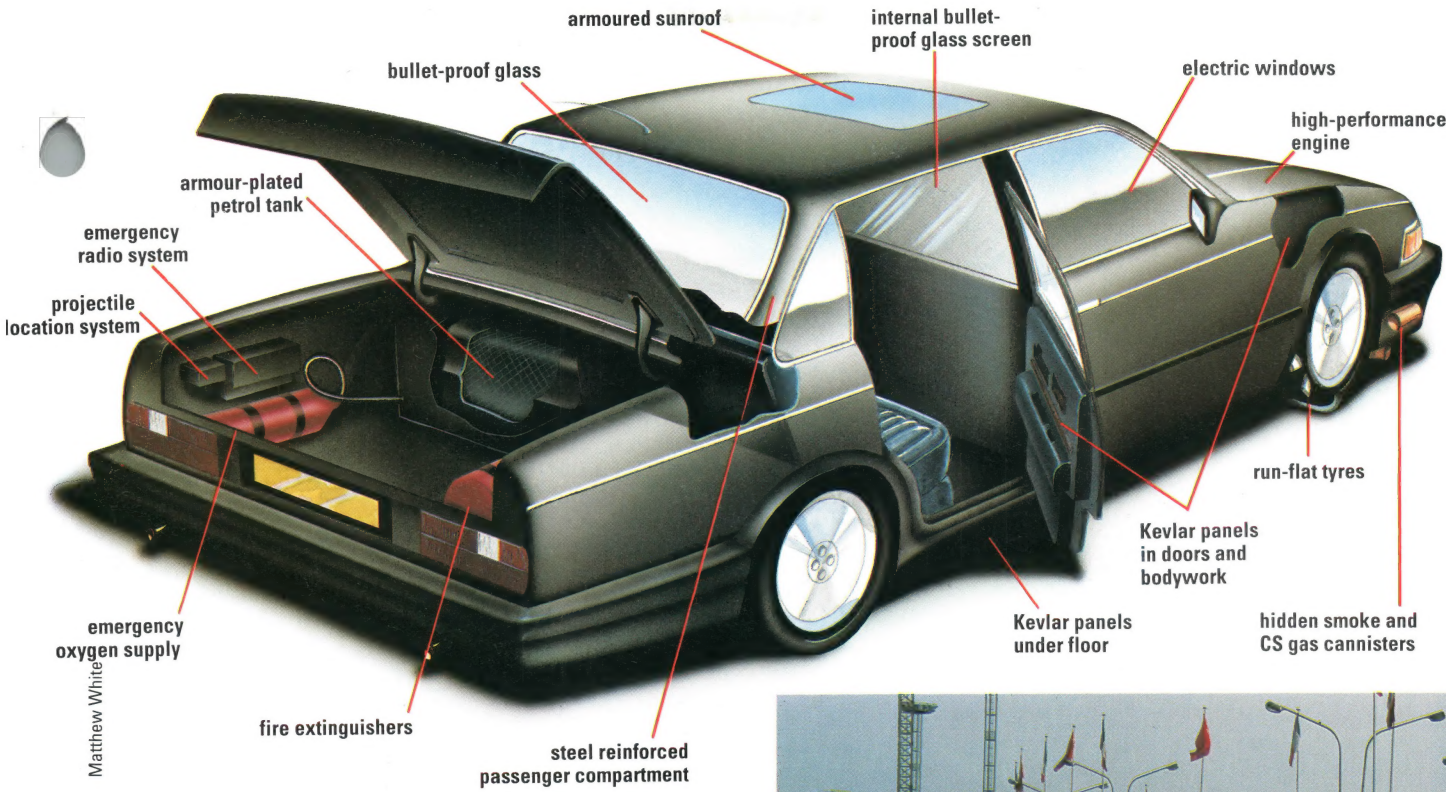
Gas chromatography analyses the air surrounding a suspected bomb. The system uses a sensor filled with a carrier gas, which responds to the unique vapours emitted by, for example, Semtex. Analysis of this gas shows whether there are any explosives present,

***'Sniffer' dogs** check luggage for explosives, but cannot detect the terrorist's Semtex explosive, which has no smell. Now aircraft passengers pass through a 'sniffing doorway', which analyses the chemicals in the air around them.*

***This bomb detector** is portable and fits into an attaché case. It can check cars, parcels, luggage and rooms, and will quickly detect the vapours given off by explosives.*



Analytical Instruments Ltd



Matthew White

ping the fire from high velocity weapons such as rifles.

While armour-plating will do the job, conventional materials like steel are too heavy to be used on VIP cars. The answer comes in the form of lightweight materials such as Kevlar plastic, which is capable of stopping bullets up to a calibre of 12.7mm.

VIP vehicles

In the case of such a car, sheets of Kevlar, or a similar substance, are likely to be installed in the door panels and in the bulkheads in front of and behind the passenger compartment. It may also be used under the car, to protect against bombs placed underneath. The passenger compartment will be strengthened to protect the car should it be blown over on to its roof.

Kevlar works like bullet-proof glass – another feature of VIP vehicles – in that it absorbs the energy of the bullet, slowing it down sufficiently to prevent it penetrating the armour. Bullet-proof glass achieves this effect by being made up of layers, or 'laminates', that are arranged so that they will slow down a bullet and at the same time prevent the glass from shattering.

Gamma/Frank Spooner Pictures

***VIP vehicles** may look ordinary, but they conceal a host of extra features. Armour-plating, bullet-proof glass and a strengthened passenger compartment help protect against gunfire and bombs.*

Rex Features Ltd

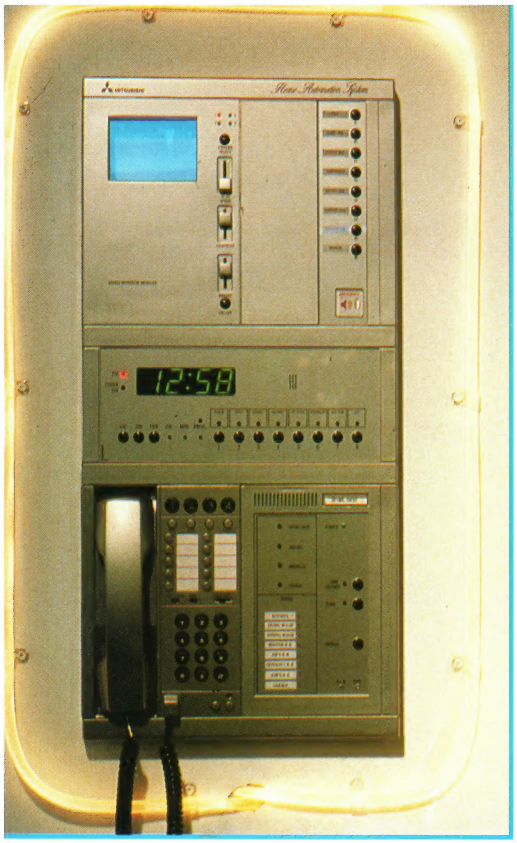
The same process is used in bullet-proof vests, which can resist shots from rifles, pistols and shotguns. A basic bullet-proof vest comprises protection for the front and back of the wearer's body from waist to neck. The armour is made of materials such as Kevlar, which is padded to make it more comfortable. A bullet-proof vest does not prevent all injuries; the wearer may suffer broken ribs or severe bruising, but will not be killed.

Protecting property

So much for life-saving technology. Just as important is security against theft and espionage. In the UK, for example, there are over one million burglaries per year, which means a burglary takes place every 30 seconds on average.

Burglar alarm systems can be simple or complex. A simple system will be linked to the doors and windows of a building, and will trigger an alarm when there is an unauthorised entry. In such a system, a wire and magnet circuit connects all doors and windows

***Full security alert** at Vienna airport. This police tank will be called into action in the case of a hijacked plane or a terrorist attack inside the airport. The policeman is wearing full body armour, and has a high-velocity rifle trained on the target plane. Police and armed forces carry out regular defence exercises to prepare for the real thing.*



Jerrican/SPL

Security systems *for the home are able to monitor every room for intruders or fire, using video cameras, sensors and a centralized computer.*

together. When this system is broken by someone forcing their way in, an alarm bell is sounded. Often, the alarm is accompanied by a mechanism which automatically dials the nearest police station, warning the police that a burglary is taking place.

But criminals have found ways of getting around simple alarms. They may cut out a small section of the window without disturbing the frame, which is wired into the system. To beat this, alarm designers have come up with new ideas such as pressure plates and sensor beams.

Pressure plates react when, for example, someone treads on them. They can be fitted under carpets or to windows, so that they go off if someone pushes against the glass.

Electronic eyes

Infrared beams are invisible to the human eye and can be transmitted across the access points of a building. If an intruder crosses the beam, the circuit is broken and the alarm goes off. In some systems, spotlights also come on as soon as the beam is broken.

Similarly, ultrasonic and microwave detectors send out beams that trigger alarms if they are broken by someone passing them.

The passive infrared detector picks up the infrared energy radiated by all objects. Human movement will cause a sudden change in the energy levels, which will trigger an alarm.

Other new types of 'key' include card entry systems, which resemble credit cards with an electronic code built into them, and digital locks, where a correct number has to be tapped out to gain access. Even more sophisticated entry systems identify individuals by their fingerprints or the unique blood vessel pattern of the eye, and then comparing them to the patterns of authorised users.

A common security device to keep out unwanted callers is an entryphone system, which allows householders to speak to visitors on a type of phone before opening the door. Some homes are fitted with a videophone system, which uses closed-circuit cameras connected to the TV set or a mini-screen.

Even more secure than houses and offices are, by necessity, bank vaults. To protect against robbers with high power drills, oxy-acetylene torches or perhaps even explosives, the walls of a strong-room are made from steel-reinforced concrete blocks, with detector strips built in to warn of intruders burrowing through. The steel doors are up to one metre thick, with a dozen or more bolts.

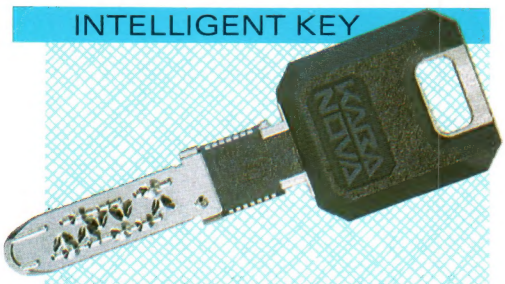
They have combination locks, with up to 100,000,000 different combinations of numbers, thus reducing the chance of a criminal 'guessing' correctly. They may also use time locks.

Very few systems would claim to be foolproof; given sufficient time and equipment, determined bank robbers can break into the strongest of strongrooms. But security measures like these at least make life much harder for the criminal, and thus greatly aid the world's police forces.

Diversion Safes (GB) Ltd

Safe inside a can. *These worthless looking cans are in fact cleverly disguised safes. No burglar would think of looking inside them for valuables.*

INTELLIGENT KEY



Kaba Locks Ltd

A Swiss company has developed an ingenious key with its own computer circuitry. This 'intelligent' key has a number of unique functions, thanks to its own integrated circuit board in the mid-section.

It can be programmed by a central command centre, which also programmes the locks in doors, windows and cupboards. The special locks decode the information contained in the key, giving total control over access to each lock. The key can even record the previous 128 movements, itemized with date and time of access.

ZEFA

Bank vaults *have doors up to one metre thick, tapered to give an airtight seal and protected by a dozen or more bolts. Combination and time locks help make them virtually thief-proof.*

COMPUTER WATCH

Telegraph Colour Library

- FRAUD AND THEFT
- SCRAMBLING SIGNALS
- PASSWORDS

COMPUTER TECHNOLOGY influences our lives in every way. For example, our medical records and information about motorists and their cars are stored in central computers; and most shops now accept payment by cards, which a computer reads to transfer payment.

The world's ecomony is run by computers in the sense that most buying and selling operations are computerized. So, if a Swedish company buys goods from a British one, a bank in Sweden will pay the British company automatically by computer.

There is also widespread computerization in the world of stocks and shares. Almost all share dealings are done by computer. In larger organizations, a computer automatically informs the operator whether a particular share should be sold. This dependence on computers makes it important that such systems are well protected from unauthorized users inside or outside the company.

Hi-tech thief

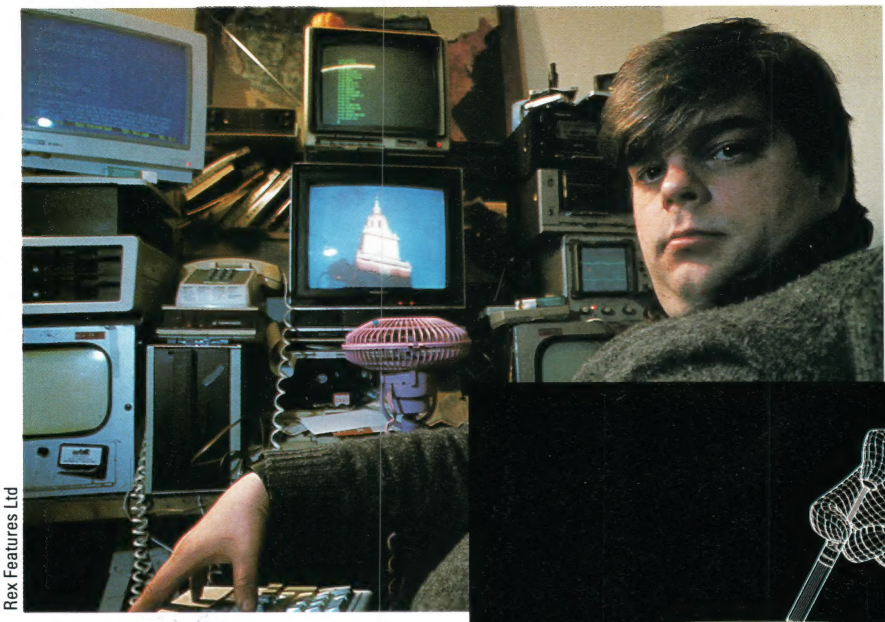
As the use of computers has become ever more widespread in everyday life, the rate of computer crime has risen alarmingly. The most common form is fraud whereby, for example, a bank employee uses his or her knowledge of the system to steal money. In one method, the thief transfers small amounts of money from a large number of accounts into one of his or her own.

Locking up the data *of a computer system is not enough to keep it secure from spies and hackers, who break in for fun or to insert viruses.*

The trick is to transfer only amounts that are too small to be readily noticeable. The thief's task is made much easier by the fact that most people do not check their bank statements, so a couple of pounds missing goes unnoticed. Also, banks deduct fees for services automatically, so the disappearance of small sums from a particular account is difficult to spot.

Eavesdropping

Another type of computer crime is the theft of information from data banks. One method is to bribe an operator to supply data from within the system. Much less risky is 'external bugging' - tapping into the



Rex Features Ltd

system from outside.

The monitor or Visual Display Unit (VDU) of a computer transmits a radio signal while it is switched on. This radio output varies in exactly the same way as the electronic signal for building up the screen image, so it is possible to reconstruct the image from the radio output, using a TV-type receiver.

Revealed

The ease with which information can be extracted was shown in 1986, when a journalist from the British newspaper *The Guardian* took part in an experiment in which such equipment was driven in a car around the town of Cheltenham. The team displayed information from banks and solicitors' offices.

This kind of bugging can be beaten by the use of 'Tempest' techniques, which cover all aspects of computer security. Tempest techniques are secret, but they are thought to include screening the VDU with materials that absorb radio waves and using small transmitters to 'scramble' the signal from the electron tube.

Tempest techniques are also used to defeat hackers — people who use their computer illegally to tap into other computer systems. Hacking began in the 1970s as a game in which people pitted their intelligence against that of the designers of security systems for computers.

On target

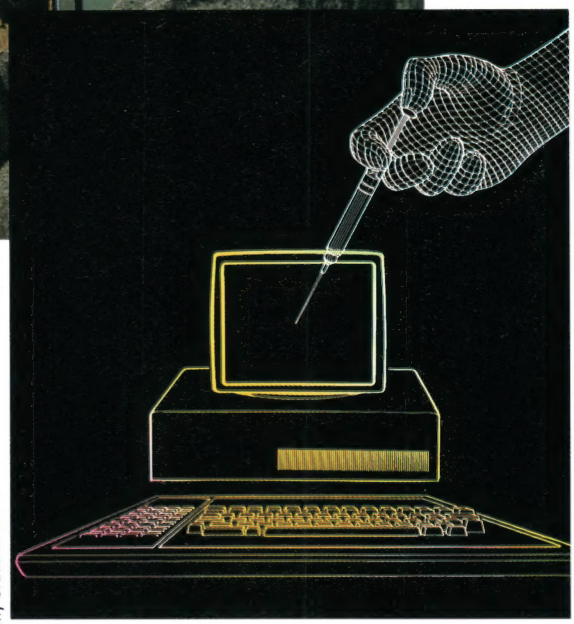
Equipped with a micro and a modem (from MOdulator-DEModulators — devices by which computers receive and transmit data by telephone), hackers can break into almost any computer system.

The first objective is to find the target's phone number. Having got into the system, the hacker then has to breach security. To give users access, many databanks have simple passwords. Finding the password may require a lot of research.

The hacker might insert into the network a 'Trojan Horse' program which gives easy re-entry without the system's operators knowing security has been breached.

Hacking ceases to be a game when it is used for espionage purposes or to introduce a 'computer virus' into a system. A computer virus is a rogue program inserted into the system to destroy it.

Once a virus has been discovered, there is no option but to shut down the system and eradicate it from the programs that guide the computer through its tasks. A virus introduced into a banking system can cause great disruption and massive expense. The same sort of program put into a hospital computer system by a malicious hacker might harm or even kill people.

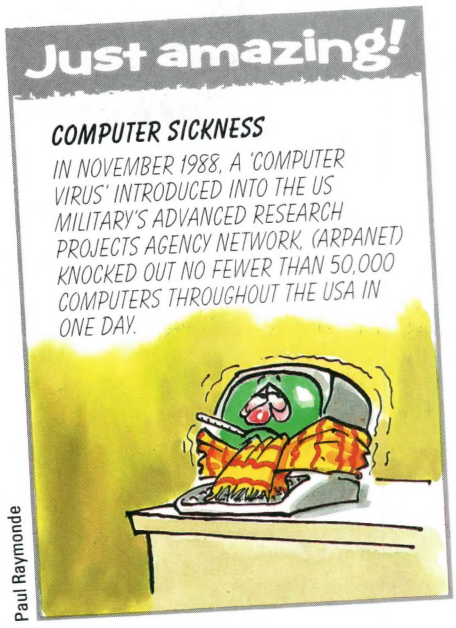


Tony Craddock/SPL

***A rogue program**, inserted into a computer system, has a similar effect to a virus in the body – it stops functioning properly. Ian Murphy, alias Captain Zap (inset left), did not intend to harm the systems he hacked into, but he was found out and convicted for computer piracy.*

***Network users**, such as banks and insurance companies, use passwords or codes to give employees access to certain levels of the system. Sometimes there is a separate network linked to the system and manned by security staff for the sole purpose of preventing fraud.*

ZEFA



Paul Raymonde

- SUBWAY SYSTEMS
- TUNNEL DIGGING
- 'EARTHSCRAPERS'

MILLIONS OF PEOPLE POUR into the world's major cities everyday on underground railway systems. Crowded, noisy and expensive to build, they are still providing the best means of public transport.

As early as the mid-19th century, city streets were so congested that plans were made to build underground railways. The first one to open was the Metropolitan Line between Farringdon Road and Paddington, London, in 1863.

The first subway in America was in Boston, followed shortly by the New York subway, the longest system in the USA with 373 km of track. The tunnel is rectangular in cross section, with steel roof beams and columns beneath concrete arches.

Smoked out

All these early underground trains were pulled by steam engines, which were equipped with condensers that turned the steam back into water for reuse. But nothing could be done about the smoke which filled the tunnels.

The New York subway has a remarkable safety record, thanks to

RATP, Paris

The Paris Métro *is considered one of the most sophisticated underground railway systems in the world. It is controlled by a centralized computer system which monitors the stations.*

GUARDIAN ANGELS

Rex Features

The Guardian Angels were set up as a voluntary crime-fighting force on the New York subway in 1979 by Curtis Sliwa and his fashion-model wife Lisa. Their intention was not to act as a vigilante group, but as deterrents to would-be violent criminals, first on the subway and then in the city at large.

Their membership soon expanded to 5,000 across 60 US cities, and they have set up 'chapters' in Canada, Mexico and London. The Guardian Angels have constantly been criticized by conventional police forces, but they have helped reduce crime levels.

Rex Features

Graffiti and violence *make the New York subway an unpleasant and dangerous ride. But more than 5 million use it each day.*

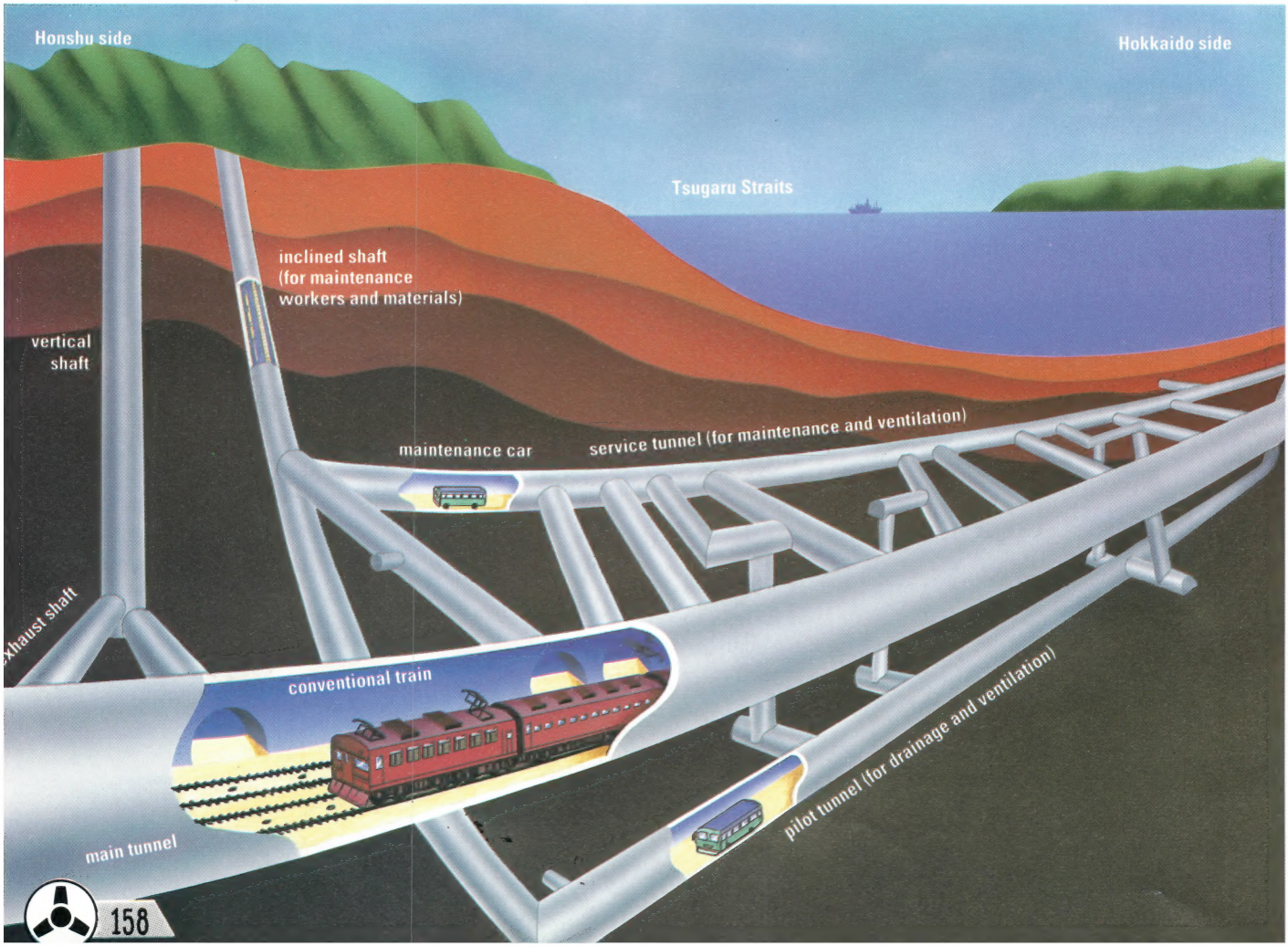
The world's longest tunnel *links the Japanese islands of Honshu and Hokkaido. Of its 53 km, only 23 km lie under the sea – whereas the Channel tunnel has 38 km out of 50 km underwater.*

its high level of automation. An elaborate signalling system divides the track into blocks, which are controlled by whichever train is in that block, thus preventing any other train from entering it.

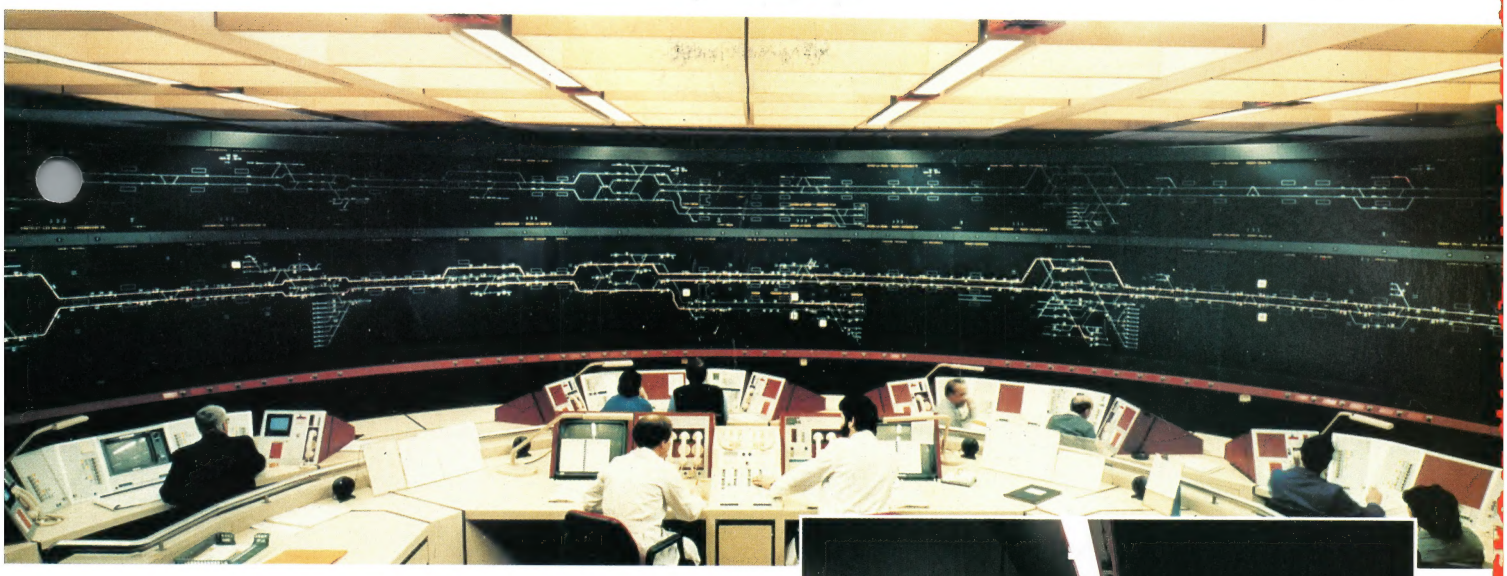
On many lines the subway has the advantage of two tracks running in each direction so that express trains, only calling at selected stations, can run at the same time as the 'locals' which stop at all stations. This also make it possible for trains to run all night on one track while maintenance work is done on the other — most systems have to shut down at night.

SUBWAY VIGILANTE

In 1984, Bernhard Goetz shot and wounded four would-be muggers carrying sharpened screwdrivers on a New York subway train. After a celebrated court case, Goetz was acquitted of attempted murder and assault, but finally sentenced to a year's prison for carrying an unlicensed gun.



Japan Railway Construction Public Corporation/Matthew White



More than five million passengers use the system daily, although it has a reputation for crime and violence.

Other subway systems run in Boston, Chicago, Washington DC and Philadelphia. The Bay Area Rapid Transport system, which serves the San Francisco region, runs for 6 km underwater along the Bay. It is very advanced technologically, with fast, light-weight carriages, automatic train control and automatic ticket collection. There are no staff, and computers in Oakland monitor the system so that carriages can be added when appropriate to ensure every commuter has a seat.

RATP, Paris

***Futuristic trains** and computerized control centres are part of the newly-modernized Paris Métro. The MF77 train has been designed to maximize space and comfort. A computer system cuts in and alerts the control centre if the driver is suddenly taken ill.*

The London Underground, with 408 km of track, is slightly longer overall than the New York subway, making it the most extensive system in the world. The distance covered by all London tube trains in a year is 49.2 million km which is the same as travelling to the Moon and back 64 times.

More than two and a half million passengers travel daily on the system, which is connected to mainline railway stations as well as the Docklands light railway. The great depth of the stations made them invaluable as air-raid shelters for Londoners during World War II, protecting 60,000 people each night.

The tube trains are slightly smaller than British Rail surface trains, and are designed to run through 3.85-metre wide tunnels at an average speed of 33 km/h. Other British cities with subway systems include Glasgow and Newcastle.

Paris Métro

The Paris Métropolitan (Métro) subway system is run by a state-controlled body which has instigated superb modernizations and extensions since the early 1970s. The result is that the Métro is now regarded as one of the finest transport systems of any world city, carrying an estimated five million passengers daily. There are 16 main lines which provide a comprehensive cover of the city, many of the stations being a short walk from each other.

The Métro is connected to the Réseau Express Régional (RER) high-speed express subway system which extends far into the suburbs and at some points has been integrated with the mainline railway network. The hub of the system is Châtelet-Les-Halles which is the world's largest and busiest underground station. The system has some unusual features compared to other subway systems, with two classes of service, special seats for the handicapped, electronic route-planners, and rubber-tyred cars.

TOKYO MADNESS

Jean Paul Nacivet/Colorific!

One of the busiest subway systems in the world is the Tokyo metro, which provides around two billion passenger rides a year on its relatively short track length. 'Pushers' have been used to pack more than 300 people into each car during the rush hours.

Like the Tokyo metro, other subways in Japan are heavily commercialized with numerous restaurants and stores. The Japanese government is currently investigating the possibility of building ultra-deep new lines more than 50 metres underground to avoid the cost of purchasing enormously expensive surface land.

Paul Raymonde

The most important form of transportation in Moscow is the Metropolitan subway. The stations are noted for their elaborate architecture and decoration with marble pillars, chandeliers and stained glass. The network is designed along a series of radial lines linked to a single ring subway. Heavily subsidized by the government, the system is the world's busiest with nine million passengers a day. Other Russian subway systems exist in St Petersburg, Kiev, Tbilisi, Baku and Kharkov.

In Canada, the Toronto subway uses steel-wheeled cars, steel rails and shallow trenches. In contrast, the Montreal subway uses lightweight, rubber-tyred trains which run through rock tunnels deep beneath the city streets.

Other major systems more than 40 kilometres long include Berlin and Hamburg, with smaller systems running in Athens, Barcelona, Budapest, Buenos Aires, Copenhagen, Mexico City, Milan, Madrid, Rome, Stockholm, Sydney and Vienna.

Electric-powered

Most of the world's underground railways are powered by direct current delivered to electric motors through a third – and sometimes even a fourth – rail alongside the track. At stations the power rail is always on the side away from the platform. On some railways the locomotives pick up the current from the underside of the rail, which is topped by a safety cover.

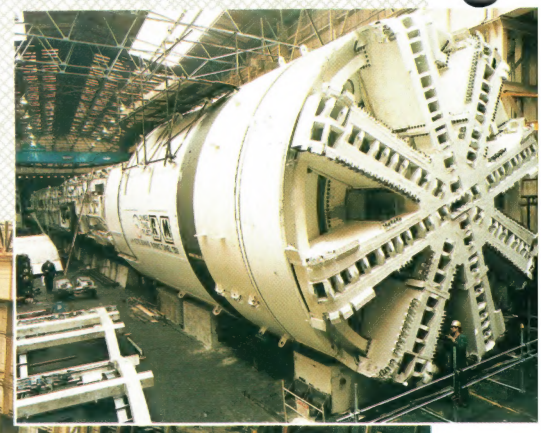
The earliest tube tunnels were built by the 'cut and cover' method, where a deep trench was dug and lined with brick or concrete. Then it was covered over with brick arches or girders to form a roof, and the excavated soil was replaced over it.

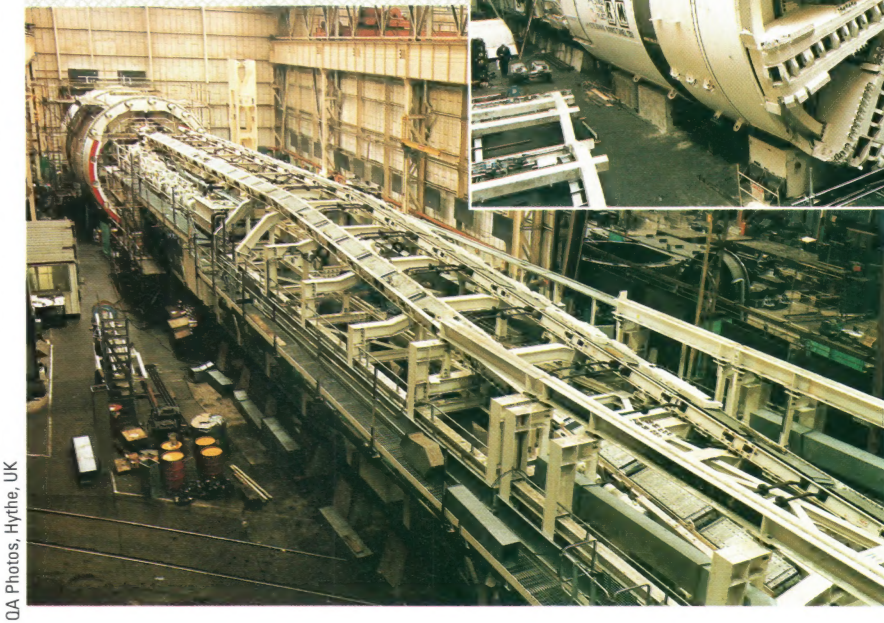
'Cut and cover' is the ideal method for tunnels near the surface. But tunnel-boring through the ground is used deeper down. In the old days, the tunnels were dug by gangs of labourers using pick-axes. Now Tunnel Boring Machines – TBMs – use rotating cutting teeth.

EUROTUNNEL

The Channel Tunnel provides an under ground rail link between Britain and France from late 1994. The twin-rail tunnel travels for 38 km under the sea, 70 metres below the sea bed, making it the world's longest undersea tunnel. It was dug through a layer of 'soft' chalk, using giant tunnel boring machines – TBMs. The TBMs had 4.8 metre cutting heads, were up to 270 metres long and bored through the rock at 1 km per month.

The French TBMs worked from the other side of the Channel and the tunnel should be fully operational by the summer of 1994. It will halve the journey time between Paris and London to three hours.



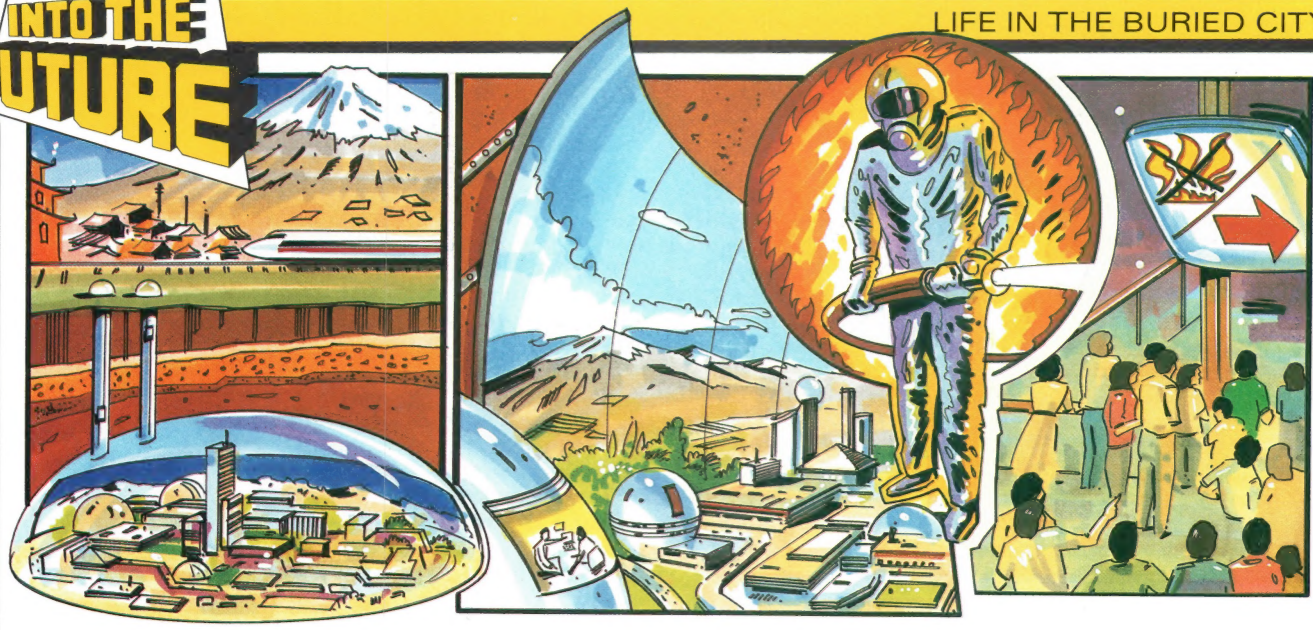


QA Photos, Hythe, UK

QA Photos, Hythe, UK

INTO THE FUTURE

LIFE IN THE BURIED CITY



Joe Lawrence

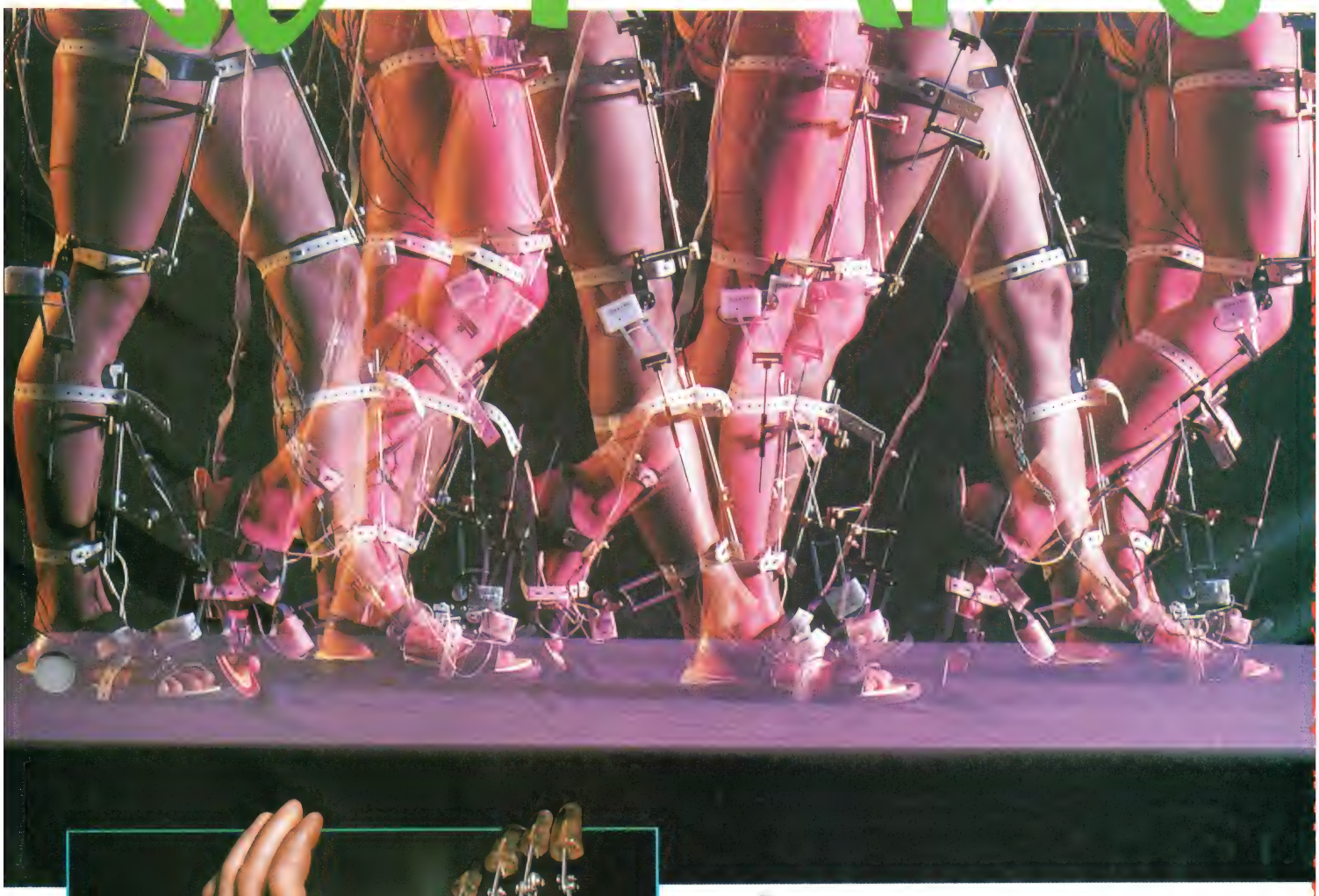
▲ *Eventually the pressure to accommodate expanding populations will lead to the construction of underground cities linked by trains.*

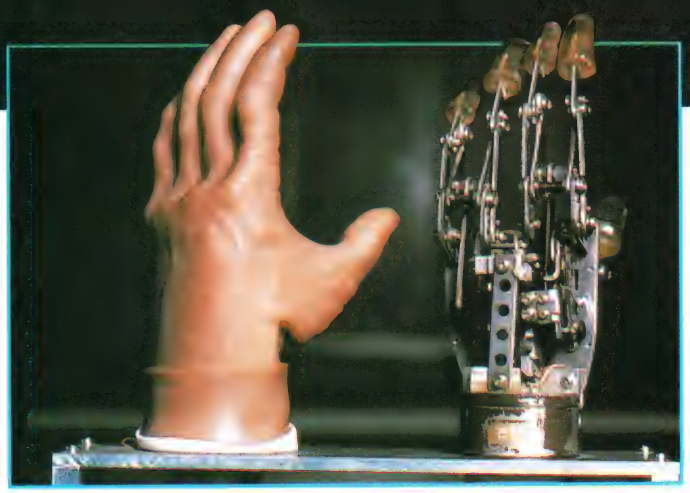
▲ *Vast high-definition TV screens would provide scenes from the planet surface, to keep the underground inhabitants in touch with the outside world.*

▲ *Because of the large fire risk, there would have to be safety zones with supplies of air and power which could be sealed off in an emergency.*

BIONIC EARS ARTIFICIAL JOINTS FACIAL RECONSTRUCTION

BODY PARTS





Claude Charlier/Science Photo Library

***Artificial limbs** can now mimic the movements of real arms and legs with the help of computer-aided designs. Electrodes detect electronic impulses from the upper limb muscles, and can re-create these signals in motors in the false parts (left).*

THE HUMAN BODY IS A remarkable machine, but one vulnerable to disease and damage. Yet just like a machine, when some body parts fail because of illness, injury or wear and tear, their functions can be taken over by artificial replacements.

For example, modern science has provided electronically controlled artificial arms for people who have suffered an amputation above the elbow. Tiny skin electrodes are attached to muscles in the upper arm or shoulder, which can be used to trigger the arm to move up or down. Signals can also be sent to vary the firmness of grip of an artificial hand, so that it can pick up an egg or crush a soft drink can. Scientists are currently developing even more sophisticated artificial hands with touch sensors in the fingers.

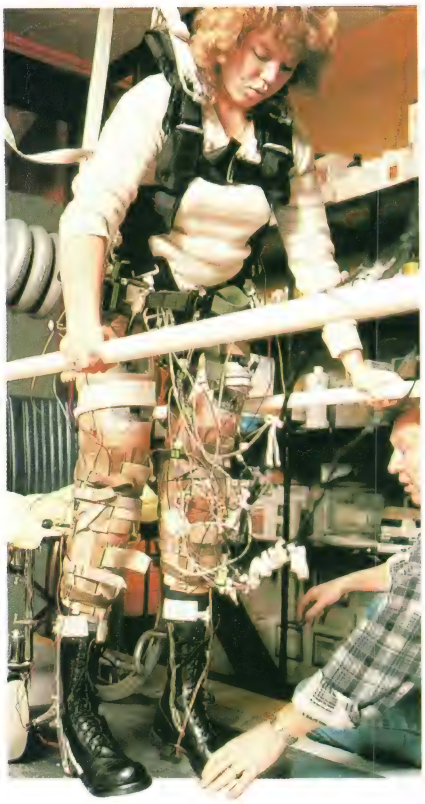
Some cases of deafness have been overcome by the use of a bionic ear. Electrodes implanted in the inner ear send messages to the brain. While ear implants have given deaf people some sensation of sound, there is still some way to go before they will be able to hear the full range of sounds.

ZEFA

Learning to walk

People with spinal injuries who have lost the use of their legs are being helped to stand and walk again, thanks to new types of electrical stimulation. By stimulating muscles in the legs via electrodes, and providing braces to support the knee joint, paraplegics have been able to perform rudimentary walking.

Bioengineers have also developed a highly durable artificial elbow, a very complex joint, which is made of polyethylene and a cobalt-chromed alloy. This joint is particularly useful for people whose joints have been destroyed by arthritis. There are also similar artificial joints



Gamma/Frank Spooner Pictures

Learning to walk *with mechanized legs is a long and complicated business.*

An artificial hip *joint, as seen by X-ray. The metal head fits into a plastic socket.*

Ian Yeomans/Telegraph Colour Library

whose ball fits into the hip socket, is removed and is replaced by a metal head. This is attached to a long stem, which is cemented into a hole drilled into the rest of the thigh bone.

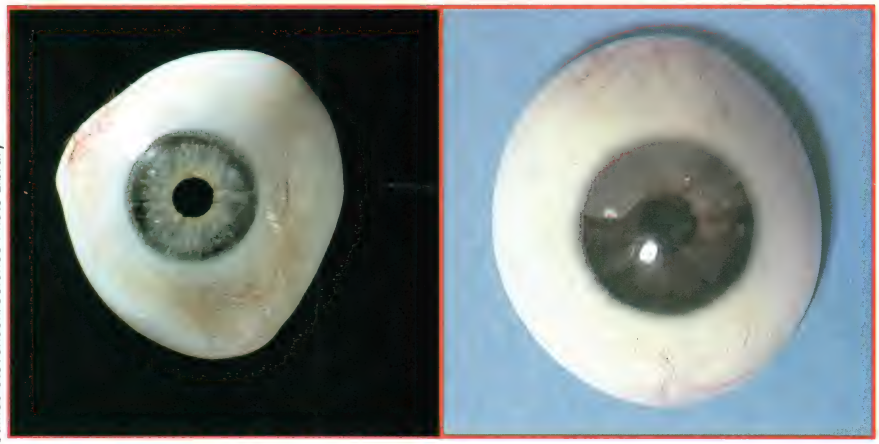
By analysing the stress forces on the hip, engineers can now produce artificial hip joints good enough to withstand the forces of the human body for more than 25 years.

Longer legs

In some tragic cases, young children have had their legs amputated because of bone tumours in the long bones. However, scientists have developed artificial bones made of tungsten carbide and incorporating a knee joint which can be attached to the remaining leg bones. What makes this implant so special is that it can be extended at various intervals by injecting ball bearings to force out a piston. This overcomes the problems of leg length previously associated with growing children. Eventually it is hoped that the artificial limb will contain a motor so that extension can be achieved by remote control.

for knees, shoulders, fingers and ankles.

Millions of people suffer hip joint damage as the result of arthritis, which can mean a loss of mobility as well as excruciating pain. An artificial hip joint has proved the answer. The last 30 years have seen great improvements in the quality of artificial hip joints made from metal and plastic. The operation involves gouging out the socket of the joint, and replacing it with a sturdy plastic cup. Meanwhile, the head of the femur, the long bone in the leg



James Stevenson/Science Photo Library

Glass eyes *come in all colours, but cannot 'see'. Tiny TV cameras may be used in the future.*

A NEW FACE

David is a young Peruvian Indian boy who had not developed an upper jaw or nose because of malnutrition or infection. Scottish plastic surgeon Ian Jackson and his wife Marjorie met David in Lima. They were later persuaded to begin rebuilding his face when they were back in Glasgow.

Ian & Marjorie Jackson

Tubes of flesh – known as pedicles – were grafted from David's body on to his face. As they 'took root', they were moulded into an upper jaw and nose, involving nearly 100 operations over ten years. The emotional trauma was probably as severe as the physical pain – but now David has a whole face.

In cases of face cancer, large pieces of bone and tissue may need to be removed. Now an artificial 'skin' can be moulded to match the remaining parts of the face, and coloured to match the skin shades. Tiny terylene fibres can even be inserted to mimic the small blood vessels under the skin. Tubes – or pedicles – of flesh can also be used to transfer 'healthy' skin from one part of the body to another in cases of facial deformity or illness.

Electronic eyes

Blindness is another disability which is being studied. Scientists have already managed to electronically stimulate visual centres of the brain to enable blind patients to 'see' silhouettes and moving objects. By the end of the century they may be able to implant TV cameras the size of hazelnuts into eye sockets to enable blind people to see.

HOME FROM HOME

FOR MANY PEOPLE, HOME may only be a temporary resting place. Soldiers, sailors and oil rig workers may spend months, even years, away from home. They need to make the most of their living quarters – so that they have a home from home.

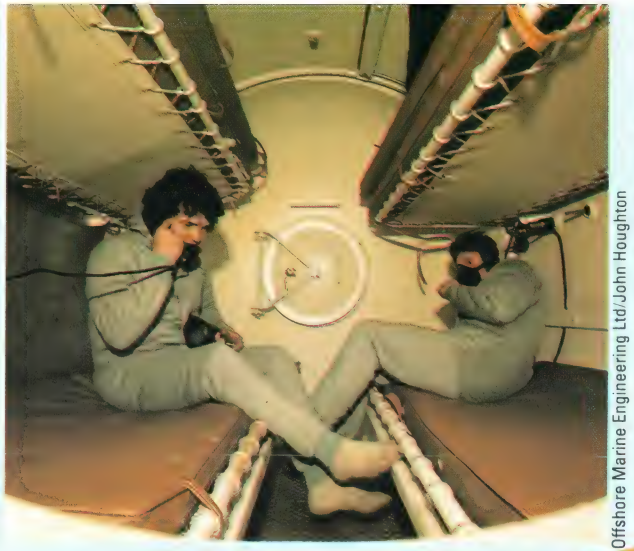
For most workers on a North Sea oil production platform, life is split into two distinct halves. Two weeks on the rig, working 12 hours or more each day is followed in most cases by two weeks off. The offshore installation manager who is in charge of the rig may be on call 24 hours a day. Saturation divers do a longer stretch of four weeks on and four weeks off and, when working, live in special decompression chambers, which match the high pressures they are under when diving deep down. The pressure 150 metres underwater is 15 times normal pressure, so a pressurised gas (helium/oxygen) is used to match this atmosphere in the chambers while they are living in them.

The 'bends'

This means that the divers only have to undergo the slow process of decompression once a month, at the end of their stint. Otherwise they would have to be decompressed after each deep dive, to prevent them suffering from the 'bends'. This is a condition caused by nitrogen bubbles appearing in the blood when a diver returns to

Exxon Corporation
Shell UK Ltd

***Oil rig workers** use huge amounts of energy and need to be well-fed. Their canteen facilities are first-class, offering a wide variety of food, flown in by helicopters.*



Shell UK Ltd

A decompression chamber. *The diver on the left is talking to the control room while his partner takes in oxygen. Food is passed through the airlock between them.*

Offshore Marine Engineering Ltd/John Houghton

Saturation Diving Vessel

A diving vessel *attached to an oil rig has several decompression chambers to house the divers. They may spend three weeks there, living at up to 15 times normal pressure, so they can cope with high pressure when they are deep underwater. They only need to undergo decompression once a month, instead of after every dive.*

atmospheric pressure too quickly.

The decompression chambers have their own sleeping and eating quarters, and televisions and videos for relaxation. Modern diving vessels also have special pressurized lifeboats for the evacuation of divers under pressure in an emergency.

Oil rigs manage to carry most of the facilities of everyday life, with the exception of pubs — alcohol is banned. Daily papers are flown in, and shops sell clothes, sweets, toiletries and, if the production platform is outside national tax boundaries, duty-free goods.

On the accommodation module, two workers usually share a cabin, with a shower and toilet shared by a second cabin. Each cabin has two bunks, a basin, cupboards and a chair. There are also recreation rooms where workers can read, write, watch TV or play snooker. There is a choice of films each day in the cinema and there is a library. Computer and photographic clubs

Rex Features

US Navy/Department of Defense

'Floating cities'. *Weighing up to 90,000 tonnes and carrying as many as 7,000 crewmen, aircraft carriers can be as long as three football pitches.*

Submarine life, *by contrast, is very cramped. Each crew member has only around 2 square metres of space to himself.*

are popular, and many platforms arrange charity bingo or quiz nights.

Exercising facilities are available, with weightlifting equipment, running machines and exercise bicycles. The canteen food has a high reputation and there is a wide range of choice. Drinking water is brought in with regular supplies.

Floating cities

The largest US aircraft carriers have a crew of over 7,000 men. A sailor mess deck will house 20–30 bunks, while junior officers will probably share with three others. A more senior officer will have his own cabin, which doubles as his office, and the highest officers have separate day and night cabins.

Most washing and lavatory facilities are shared. Fresh water is carried in tanks, but a condenser system turns sea water into fresh water – on newer ships a chemical exchanger separates the salt from sea water.

Satellite dishes can receive and transmit television programmes, and films are shown two or three times a week. There may be 250 men working in the canteens and galleys, preparing a wide range of food. Civilian teachers help sailors continue their high-school or college education, and a chapel serves all religious denominations.

Aircraft carriers have far more space than other ships, which means they are ideal for concerts or parties. Entertainers can be specially flown in. Traditional team games can also be played, as long as they are adapted to suit the surroundings, and there are aerobics and fitness sessions.

Life underwater

The crew of a nuclear submarine may spend months away from home. There may be weeks without daylight, no change between night and day and only the clock and calendar to show what day it is.

Everything is shared in these cramped conditions, where space is at a premium, and a man's bunk is his only personal space. Sometimes even this may have to be shared. With men on shifts to keep watch 24 hours each day, some will sleep while others work.

The ship has to be self-sufficient for months on end, and good food is important in these confined circumstances. Huge refrigerated stores hold enough food, together with tins and dried foodstuffs, for around four months. Bread is made daily. The air is recycled using a system that removes the CO_2 from the air. But it does not remove smells, so the aroma of food can stay for days.

One of the main problems of

ZEFA

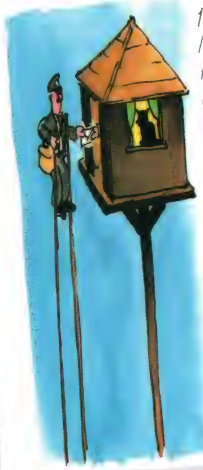
DOWN A FOXHOLE

For members of the British Special Air Service (SAS), a temporary home may be nothing much more than a hole in the ground. When acting invisible, it is important to leave no traces, so excrement is always buried. Smells associated with man, such as deodorant and soap, are too revealing – an unwashed human is much more likely to remain unnoticed.

Army rations include water purification tablets, waterproof matches and highly nutritious tinned foods that can be eaten both cooked and uncooked. The SAS also learn to trap game and fish and to identify edible fungi, seaweed and other plants. Survival training also includes evading dogs by wading through water or hiding among farmyard animals whose scent covers their own. In the army they say you can recognize an SAS man by the way he walks backwards through the snow!

Just amazing!

HIGH-LIVING



Paul Raymonde

19-YEAR-OLD MELLISSA SANDERS FROM INDIANA, USA, SPENT 18 MONTHS, FROM 1986–1988, LIVING WITH HER CAT IN A 2 X 2.5 METRE HUT ON TOP OF A 13 METRE POLE. HER MOTHER HAD SET A PREVIOUS RECORD OF 211 DAYS (7 MONTHS) IN 1959.

Life on the road. *The sleeping quarters of some long-distance trucks can be very luxurious. This US truck carries enough fuel to run from Los Angeles to Chicago non-stop, over 4000 km.*

Mark Greenberg/Visions/Colorific!

CopyWriters

No room to spare. *Dick Rutan looks out of the cockpit of the record-breaking aircraft Voyager, which flew round the world non-stop in 9 days. His co-pilot Jeana Yeager shared flying duties in the tiny cabin.*

living like sardines – space works out as 2 square metres per man – is the lack of chances for normal exercise. So there are exercise bikes and weights available.

Raw sewage is held in tanks and reduced biologically before being pumped out. This has to be done carefully to avoid giving away the submarine's whereabouts. The sonar equipment is so sensitive that it can detect a ship above by a door shutting. Operators even get to recognize individual ships by the noises they make!

Living on the wing

Dick Rutan and Jeana Yeagar spent 216 hours in the cigar-shaped cockpit of the aircraft Voyager in December 1986. The 40,000 km trip was the first round-the-world non-stop unrefuelled flight.

Flying duties were shared in the tiny cabin, which was enclosed by a close fitting bubble canopy. The non-flying crew member slept in a bed behind the pilot and changing places involved one climbing over the other – a dangerous procedure taking about a minute while the plane was on autopilot.

They wore special pyjama-like flying suits designed to maintain body temperature and absorb sweat. Sponge baths were the only way they could wash. They had a tube system for urine relief, and the only things they were allowed to jettison overboard were fecal bags (usually used for critical care hospital patients). These went through a hatch in the floor.

Plenty of drinking water was taken on the trip to avoid dehydration and blood coagulation. Food came in sealed packets and a portable element was used to heat it.

The workload only allowed about two hours sleep per day.

Joe Lawrence

▲ *Man's quest to colonize other worlds will lead him to build cities within giant self-standing structures on the surface of the Moon and Mars.*

▲ *All the resources of planet Earth will have to be built into these 'geospheres' in order to create a self-sustaining ecosystem in which life can flourish.*

▲ *Life inside would be a replica of life on Earth. Eventually, a generation will evolve that will regard the geosphere as home and Earth as the distant mother planet.*

SIMULATORS SOFTWARE VIRTUAL REALITY

WONDER WORLDS

PILOTING SPACE PROBES TO Mars, driving Formula 1 cars around Grand Prix circuits, or facing life or death struggles against inhuman monsters – today's computer games are capable of providing a totally new world of wonder and entertainment.

Electronic games, in arcades and at home, have come a long way in the last ten years. In the early days, the graphics and sound effects were frequently both clumsy and unconvincing. Now, though, thanks to some remarkable advances in computer technology, pictures and accompanying sounds of stunning quality can be produced. In the best games, the player becomes totally involved in an imaginary electronic world that he can control with a wide variety of switches, pedals, joysticks or keypads.

Fast response

At the heart of every electronic game is a computer running a program. In a coin-operated arcade machine, or 'coin-op', the computer usually contains a number of special-purpose chips. At the factory, these chips have the game's program installed into

***Mechwarrior**, the latest US arcade game, is unique among simulation games in that players embark on missions in teams, with each member in command of his own vehicle. Each cockpit is controlled by three computers, linked via a local area network to the others.*

FASA Corporation, Chicago

Deith Leisure plc

ZEFA

***Pinball games**, under the control of microprocessors, are far from dead. Arcades offer a wide variety of different scenarios.*

handle much larger memories and to process information a great deal faster than previously possible.

Software

Instead of the primitive, 'chunky' graphics of 8-bit micros, the latest 16-bit machines can generate realistic, moving pictures with a fantastic range of colours and textures. At the same time, the scope for computer games has never been wider or more promising.

A huge choice of recreational computer software is now available. But, basically, most computer games fall into three main categories.

First, there are arcade action games, in which a common goal is to shoot down as many of the enemy as you can before they shoot you. This makes them ideal for use in amusement arcades since they demand little or no experience and usually end quite quickly. To keep skilled players interested, however, several levels are programmed in, each one harder than the one before. Hundreds of such games have been developed for video arcade machines and home computers, and even in tiny, hand-held versions fitted with LCDs (or liquid crystal displays).

Make believe

A totally different kind of challenge is offered by computer adventure games. Here the object is to find a way through an imaginary world, such as an underground maze of tunnels and caves. In the computer's memory are stored the details of each location in the maze so that this can be shown on the screen as a colourful picture. The computer also keeps track of the adventurer's possessions, weapons, and state of health, as well as the whereabouts of any creatures that may be lurking within its make-believe world.

An interesting feature of adventure games is their use of simple artificial intelligence to understand and communicate with the person playing. The computer has to be able to scan a short sentence given to it, extract the meaning, then act accordingly.

Laser disc

An adventure may take many hours, or even days, to complete. When faced with a particular problem, the player often has to stop and think before being able to move on. For this reason, few adventure games have found their way into amusement arcades.

One notable exception is *Dragon's Lair*, a spectacular arcade game in which moving cartoon pictures and sounds are stored on a laser disc. At various stages in the adventure, the player has to make snap decisions and sometimes fight a monster on the screen using the controls provided. Depending on what the player does, the computer jumps to one of several new points on the

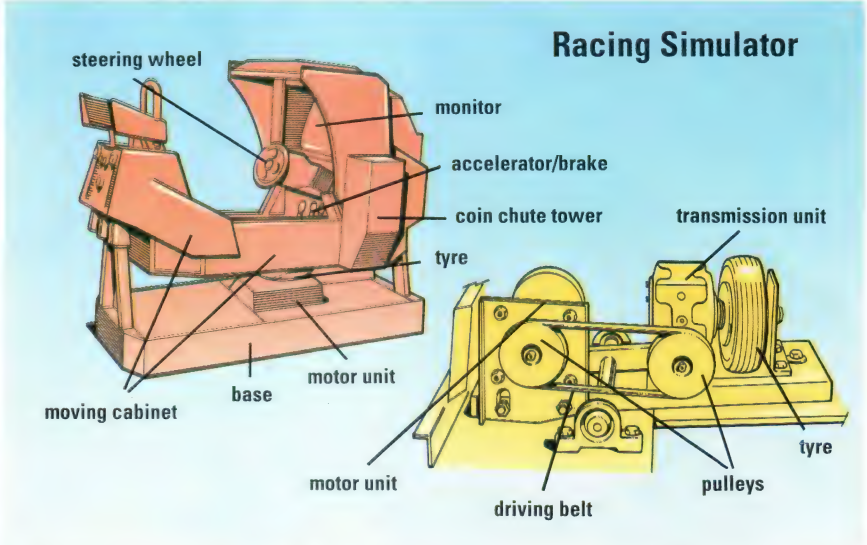
them. The result is a game that can be played at very high speed and that responds instantly to the control sticks or pedals.

By contrast, the chips inside a personal computer are general-purpose. In other words, they can be loaded with many different games programs, as well as other types of software, although they may not work quite as fast as a 'coin-op'.

Today, most new microcomputers are built around chips that work with 16 bits, or binary digits (ones and zeros), of data at a time, instead of just 8 bits. This allows them to

Sittler/Jerrican

***Arcade games** can be made more enticing if player participation is increased. One way of achieving this is with a light gun, which can fire at on-screen targets.*



Joe Lawrence

***Simulator games** feature a moving cabinet, driven by a microprocessor-controlled motor, which turns a tyre against the base of the freely swivelling cabinet in which the player sits.*

laser disc where the story is continued and combat resumed.

Simulations are a third category of computer game, in which the object is usually to fly an imaginary aircraft. On the screen, the plane's dials and instruments are shown, together with the view through the front window.

Aerial dogfight

As the player-pilot operates the controls, the computer works out the effect this would have on the aircraft from one instant to the next. The more elaborate simulations let the player choose from a range of different aircraft, weather conditions, and airports around the world.

Not only are the graphics and sounds of electronic games becoming more realistic. Some of the latest arcade machines incorporate a powered chair that throws the rider around as if in an aerial dogfight or 'Star Wars' shoot-out. the British company, Konix, now even offers such a chair linked to a screen and games console for use in the home.

A further variant of the simulator game is the 'games centre'. Pioneered by the ESP Corporation of Chicago, US, these centres feature simulators that are linked by both radio and computer so that the games can be played in teams. Players pay for a half-hour game that includes training and strategy sessions and ten minutes of actual play.

Every game involves a different mission and assortment of combat vehicles. Even the terrain and time of day changes – it may be daylight, dusk, or night. And because humans make the decisions, the possibilities are endless.

Controlling each cockpit are three powerful computers, linked via a local area network to the computers inside the seven other cockpits. A massive, 32 million-character memory holds 19,000 graphic images that can be called up and manipulated by the battle simulator. The result is that each player sees, from his own perspective, a realistic, ever-changing view of the action taking place.

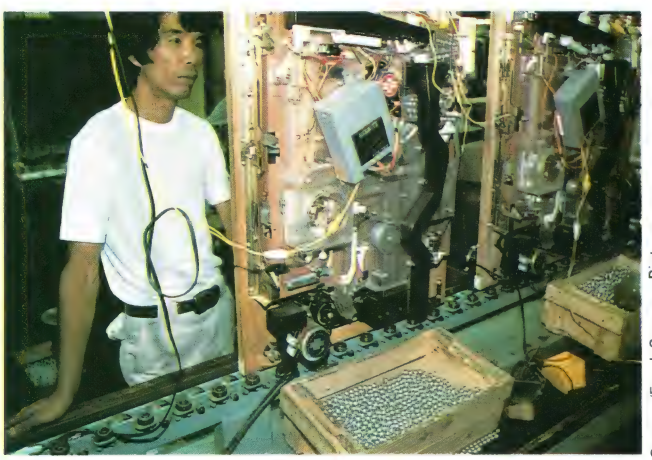
Eye-Phone

The first of these games was MechWarrior and the so-called 'BattleMech' cockpits simulate land-based vehicles. Future versions, however, may let players fly in anti-gravity tanks or dive in mini-subs to search for a sunken ship.

ONE-ARMED BANDITS – NO-WIN GAMBLING

Rex Features

However skilful a player thinks he is, a fruit machine can never be beaten. Not even luck can help because the machines are controlled by special computer programmes to pay out about 70–80 per cent of the money fed in. This figure has been calculated, through experiments with people and apes, to provide maximum addiction. The revolving reels do not spin due to momentum but are attached to stepper motors that move as instructed by the on-board computer. When the reels stop just one position short of a win they are simply obeying a computer command given before the player even started them spinning.



Gamma/Frank Spooner Pictures

Assembly line *in a Japanese factory, making the highly popular arcade game called pachinko, played with small balls.*

Rex Features

Home computer games *offer arcade quality sound and graphics with powerful, 16-bit (binary digits) microprocessors. Games come on cartridge or disc, depending on the system. A joystick, often incorporating a fire button, offers rapid control.*

Just amazing!

REAL FANTASY

IN 'REALITY BUILT FOR TWO' TWO PEOPLE CAN SHARE THE SAME VIRTUAL REALITY – WITHOUT LEAVING THEIR CHAIRS. THEY CAN SHAKE HANDS AND EVEN STROLL THROUGH THE COMPUTER'S SIMULATED WORLD.

Paul Raymonde

As with other arcade games, novelty is all-important and it takes just 20 minutes to reload the system with a fresh set of graphics and brand new software.

Power glove

A still more amazing effect is that created by 'virtual reality', where the user dons a special helmet and glove linked to a computer. The helmet, known as an Eye-Phone, shuts out the real world and replaces it with a computer-generated landscape displayed on a miniature TV screen. As the wearer moves his head, sensors in the Eye-Phone detect this movement and cause the computer to sweep to a different part of the imaginary scene. Similar sensors in the glove, called a Power glove, detect the slightest movements of the wearer's fingers. The result is that a person can actually pick up objects he sees in the computer-made world as if they were real.

In the future, 'virtual reality' may be extended to allow an unlimited number of people to take part, even if they are located thousands of kilometres apart. Photographic-quality graphics, 'surround-sound', and devices like powered chairs will gradually make the computer's fantasy worlds seem amazingly real.

If 'virtual reality' is not real enough, then one can embark on a combat game. Primitive but hugely popular throughout the world is 'paintball adventuring'. This is a team activity for groups between 10 and 100 people. The paintball adventurers are armed with air pistols, accurate up to 35 metres, that fire harmless, biodegradable paint pellets that wash away with water.

Painted out

Each player is provided with protective goggles, visor, headcovering and camouflage overalls and is 'eliminated' if hit by a paint pellet. The basic game involves two teams whose objective is to capture a flag from the enemy's camp and safely take it back to their own flag-camp.

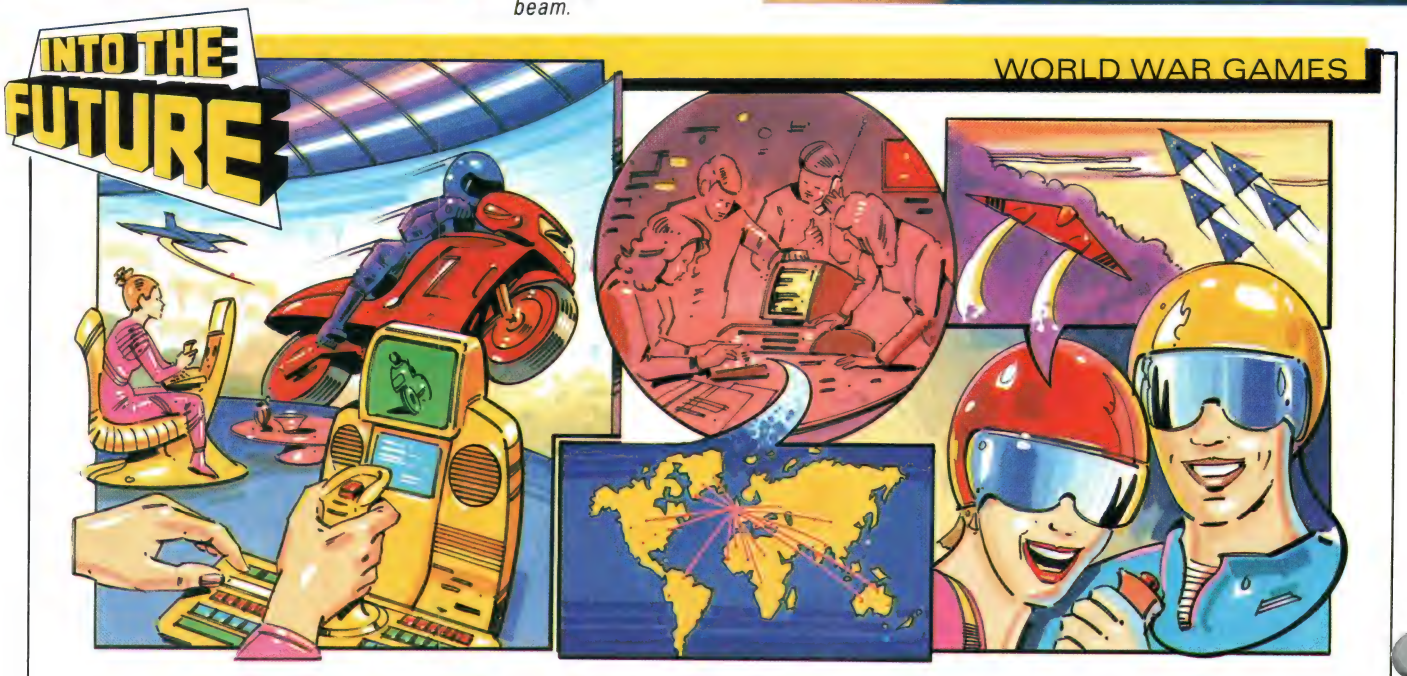
Nintendo of America Inc.

Serif Games

The power glove *plugs directly into the computer. Sensors in this programmable glove allow finger and hand movement to control objects and characters on the screen (above) and 'customize' games.*

Photon Warrior *is an electronic combat game in which two teams of players battle for supremacy in specially constructed rooms. Each player has a chest pod that records 'hits' from guns that emit an invisible, infrared beam.*

Colorific!



▲ *Future games players will enter an enclosed game capsule in the home, equipped with 'sensurround' sound and high-definition, 360° graphics.*

▲ *Many players around the world, either individuals or team groups, will be able to take part in the same fantasy through global computer networking.*

▲ *'Virtual reality' headsets will completely shut out the real world and replace it with a computer fantasy within which the players can pit their wits.*

Joe Lawrence

- ROLLER-COASTERS
- SPINNING WALLS
- SPACE TRIPS

Rex Features

TERROR RIDES

The Shock Wave *in Dallas consists of two large loops following in tight sequence. The train reaches a height of 30 metres. Centrifugal force ensures passengers remain firmly planted in their seats even when travelling upside down (inset above).*

THE BEAST HURTLES DOWN an almost sheer drop. Its victims, held securely in its grip, scream as they approach the final twist.

All new amusement park rides are designed with the help of computers and tested thoroughly as prototypes before anyone is allowed to step into them. Once in operation, technology ensures the ride runs smoothly, while providing the maximum number of thrills. Sensors indicate whether or not the safety bars are down and locked and a computer will operate the ride.

Ready to roll

All roller-coasters work in the same basic way. At the start of the ride, the cars are hauled up a long, steep incline by a continuously moving set of metal teeth. Having reached the top, the teeth disengage and the cars roll down the other side, rapidly gathering momentum. As they

Hank Morgan/Rainbow

Robert Harding Picture Library

ROLLER HORROR

On a sunny afternoon in June 1987, 19-year-old Karen Brown and her fiancé climbed on to the Lightnin' Loops roller-coaster in New Jersey, USA. As the safety bars came down in front of the other passengers, Karen's snapped shut behind her. The computer sensors indicated that the safety bars were down and locked. Karen screamed to the operators, but, once started, Lightnin' Loops could not be stopped on its 30 second, 65 km/h circuit. Karen reached the top of the first loop and was tossed 23 metres on to the concrete below.

Such accidents, however, are rare. The chances of dying on a fairground ride is one in 66 million – small even in comparison with the risk of dying in a plane, which is one in five million.

Guido Alberto Rossi/Image Bank

Wooden roller-coasters *cannot offer loops, but instead provide groaning timbers, sheer drops and zero gravity as the cars speed over small humps.*

fall, the potential energy the cars acquired at the top of the slope changes into kinetic energy (the energy of motion). Travelling at speeds as high as 100 km/h, the passengers may go in less than one second from a downward slope of more than 45° to an upward slope of the same angle. The stomach-wrenching feeling that results is caused not by the sudden change of speed, but by the sudden change of direction.

What comes next depends on the particular ride. With corkscrew roller-coasters, the cars hurtle up and over a complete, vertical loop. From the ground, it may seem as if the passengers are in danger of falling out. But nothing could be further from the truth. As the cars circle around, the people are actually pressed into their seats. In a similar way, water in a bucket will not come out if you whirl the bucket round fast enough. This phenomenon is called centrifugal force (from the Latin meaning 'centre fleeing').

As the centrifugal force pushes outwards, the track 'pushes' the cars in. This inward force is called centripetal force (from the Latin meaning 'centre seeking').

Hanging on

The top of the first loop in a corkscrew roller-coaster has to be quite a bit lower than the top of the slope that came before it. Otherwise the cars would not be able to gain enough momentum to get around. In the same way, any further loops must be successively lower. If the ride is long, it may have more than one section where the cars are towed back to a considerable height before being released again.

Experiencing a greater gravitational force (G force) is an important part of the breakneck thrills of a roller-coaster ride.

One G is the force of gravity we normally experience; it is what ensures that we remain planted to the ground rather than drifting into Space. On the Moon there is a force of one sixth of a G, which makes an astronaut on the Moon feel very light. A roller-coaster ride can impose a force of up to six G on the passengers. This makes the body feel extremely heavy.

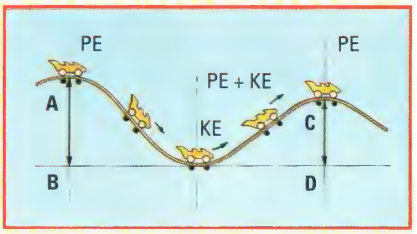
On a roller-coaster ride, the passengers only experience up to six G for a split second. Six G has a similar effect on the body to a tourniquet around the neck: it cuts off the blood supply to the head. A person can survive for only five seconds without this blood supply before he

Robert Harding Picture Library

Hi-tech steel *allows freedom in design. At Wonderland in Canada, the Dragon Fyre combines vertical loops with a corkscrew and a helix (a screw-shaped coil).*

Centrifugal force *pins the passengers to the wall of the Roundup. Sometimes the floor is lowered so the passengers are left suspended in air – the force ensures they do not fall.*

COASTING ON ENERGY



John Houghton

A roller-coaster car at the top of a slope has energy. This energy can be used to move downhill at speed. This is called gravitational energy. Gravitational energy can be stored until the operator is ready to let the car go. Energy that can be stored is called potential energy (PE). Once the roller-coaster is moving, the potential energy changes into the kinetic energy of motion (KE). When it reaches the top of the second slope it changes back to potential energy again. Note that C is lower than A.

The car cannot climb to the same height as the original summit because some of the original store of energy has been lost to friction against the track and to air resistance.

becomes unconscious. Death occurs shortly afterwards.

Even at two G, the blood supply to the head is restricted. When people pass out on a roller-coaster it is probably the result of the increased G force rather than shock.

The first roller-coaster was built in 1884 in Coney Island and it reached a maximum speed of only 9 km/h. Roller-coasters have advanced considerably: the Riverside Cyclone ride in Massachussetts begins with the cars accelerating from 0 to 96 km/h in just 3 seconds.

Alton Towers

The fastest ride of all is the $8 million Magnum XL—200, opened in 1989 at Cedar Point, Ohio. Following a vertical fall of 59 metres, the Magnum reaches 116 km/h — the speed limit for British motorways.

The record for the longest ride is held by the Beast, at Kings Island, Ohio. Its 2.25 km long track includes 244 metres of tunnels, a drop of 43 metres and a 54° banked helix.

The King Cobra *in Ohio, is the first roller-coaster in the USA with standing room only. The cars speed down the track at 88 km/h and enter a 20 metre high, 360° vertical loop, then a 560° horizontal loop.*

The Corkscrew *at Alton Towers in England. Passengers travel at 65 km/h and experience a G force of 3.14 on the first drop.*

Kings Island

In their efforts to come up with the ultimate experience, roller-coaster designers are even rethinking how the cars are held to the track and the passengers to the cars. One approach is to suspend the ride from the track on cables. Another is for the passengers to stand rather than sit.

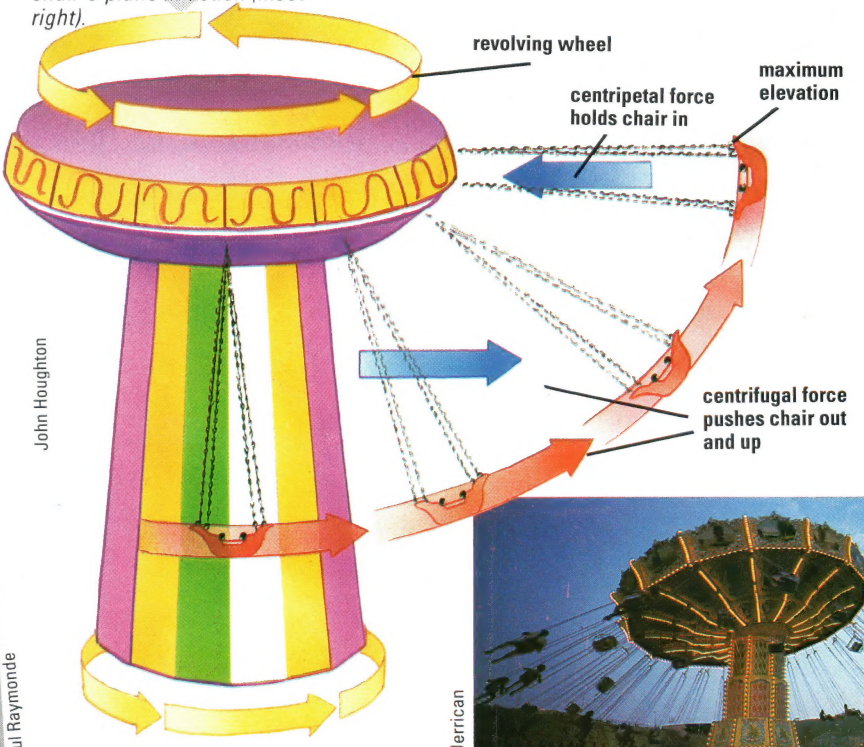
Revolving room

A quite different sensation comes from being spun round and round very quickly. On a ride sometimes called the 'Roundup', people are apparently stuck to the inside wall of a revolving room. The principle behind this is the same as that of the corkscrew roller-coaster. The wall of the ride 'presses in' to keep the passengers moving in a circle, while they are held in place by centrifugal force.

Into Space

Some rides now make use of simulators, similar to those used by test pilots. One of Disneyland's most popular attractions is 'Star Tours'. Passengers take their seats in a 'shuttle' and a panel lifts to reveal the view through the forward window. The 'window' is a video screen and the spacecraft itself is a large simulator that lurches violently in time with the action on screen. Without actually going anywhere, the passengers feel they are speeding through space.

As they spin*, the chairs are flung outwards by centrifugal force. The chains, as agents of centripetal force strain against the outward push. The two forces working in opposition cause the chairs to rise. The chair-o-plane in action (inset right).*



John Houghton

Mura/Jerrican

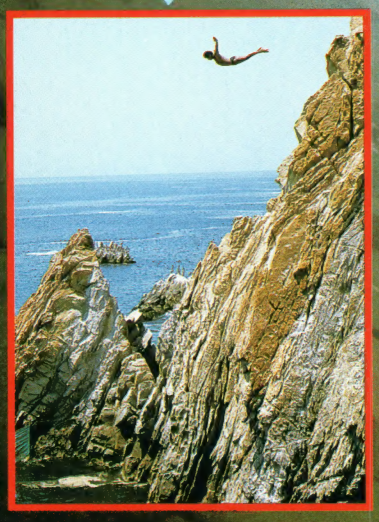
Just amazing!

BUMPY RIDE

IN 1983, AT PARC MELMONT, MONTREAL, DANIEL GLADA AND NORMAND ST PIERRE RODE ON A ROLLER-COASTER NON-STOP FOR THREE WEEKS.

Paul Raymonde

Divers in Acapulco, Mexico have to make an 8 metre leap outwards to avoid hitting the rocks 88 metres below.



Rex Features

Rex Features

Evel Knievel, here sizing up a leap at Wembley, UK has attracted more attention than any other daredevil mainly because of his spectacular failures.

ZEFA

Human cannonball, Eddie Boldizsar is 'fired' from a cannon into a safety net.

Telegraph Colour Library

The Red Arrows, in formation over Kent, southern England, are one of the most successful aerobatic teams in the world.

Stunt motorcyclist David Hodgson rides his machine through a 'wall of fire'. Travelling at speeds over 80 km/h ensures safety.

Gamma Frank Spooner Pictures

Rex Features

American Max Beck entered the record books for wearing a mantle of 100,000 swarming bees, weighing 12.48 kg, in New Jersey, in 1987.

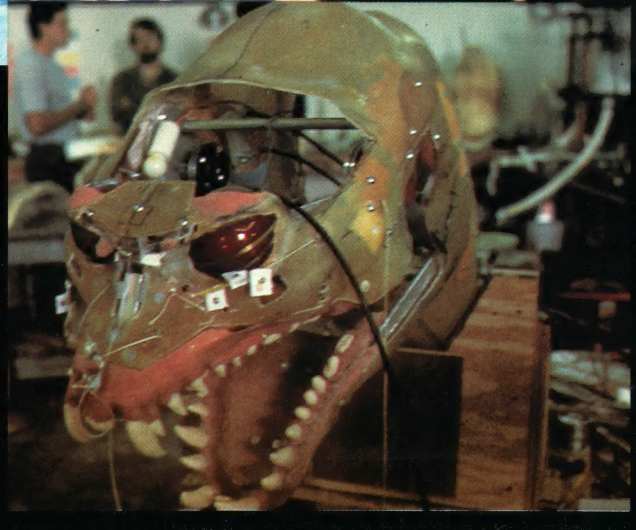
Tightrope walker Philippe Petit during his epic 1989 performance on a wire strung between the Palais Chaillot and the Eiffel Tower.

Telegraph Colour Library

WOUNDS AND BURNS LIVING SLIME MONSTERS

MONSTER MOVIES

***Stone gargoyles** come alive at the climax of* Ghostbusters *thanks to the ingenuity of the modelmakers (below).*



Columbia/Kobal Collection

Columbia/Kobal Collection

CREATING CREATURES FROM black lagoons, changing harmless-looking actors into ravening werewolves, making scars, wrinkles or rivers of slime – all are everyday work for the movie make-up men.

The art of making monster movies is to make the unbelievable seem real. Doing this is part artistry, part alchemy and part illusion. To age an actor, for example, nonflexible collodian – a liquid plastic – can be brushed on to the skin, drying and shrinking it to form wrinkles. Similarly, hair can be dyed grey or white and restyled.

Collodian is also used to make scars but, where more gruesome effects are required, gelatin, coloured with food dye, is brushed on to the skin, then sculpted as necessary. Many of the scars, wounds and burns seen in the *Star Trek* movies were created in this way.

Formula blood

Fake blood is available in several forms. One of the most popular varieties is 3M blood, made by the 3M company. But dissatisfied with the way that it looked on screen, Tom Savini, one of the leading make-up artists, created his own formula – a mixture of flour, water, red food colouring and peanut butter!

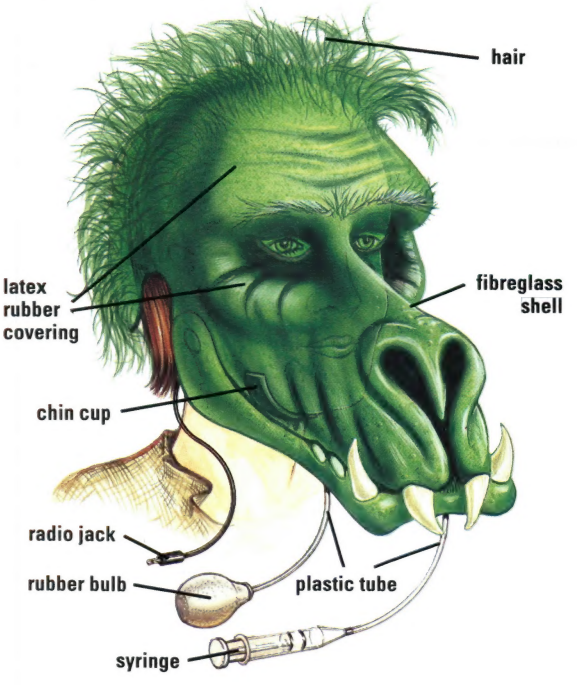
In *Ghostbusters II* the script called for a 'river of slime, which threatens to engulf the whole of New York City'. Created by special effects man, Joe Day, the 450,000 litres of slime was a mixture of liquid, vegetable-based methocel and universal food colourings. To make it 'live' as the script required 'diamond dust' – the material that gives the sparkle to metallic paint – was added and the

***A mask** is given life with a syringe-operated tube that drips 'saliva', a squeeze ball to simulate breathing and a radio jack for communicating with the film director.*

***Make-up** artists transform an actor into a werewolf – in a marathon 10 hour session – for John Landis's* American Werewolf in London.

Universal/Kobal Collection

Monster Mask



David Gifford

slime agitated with pumps and shot in slow motion.

The most spectacular effects, however, are nearly always illusions. For example, in *Friday the 13th* a sequence in which an axe crashes into a woman's head. In fact the sequence was made up of three distinct shots – the screaming actress and the real axe, a foam rubber axe and a false head – intercut to create the illusion of continuity. Such sequences are known as 'continuity tricks' and are the basis for many movie effects.

When a movie calls for strange living creatures, such as gremlins, aliens or a giant ape, then it is to the model-maker that the filmmaker turns. The oldest technique for making a model monster 'live' on screen is known as stop-motion/photography. This technique, used for the model ape in *King Kong*, involves exposing a single film frame of the model, moving it a little, then exposing another frame.

Moving models

When the film is rewound and shown at its proper speed the model appears to move. Stop-motion master, Ray Harryhausen, used this technique to create the Medusa and other monsters from Greek mythology in the lavish epic *Clash of the Titans*.

Other film creatures, such as the gremlins and E.T., were sophisticated puppets, often with on-board computers. In *Aliens*, for example, a 4-metre puppet of the monster was moved by a network of hydraulic, manual and cable controls. In scenes where the monster was mobile a 1-metre puppet was used, operated by 49 cables, five puppeteers and four technicians.

Little secrets

Apart from the six models used for the alien, E.T. was played by two midgets, 78-cm tall Tamara de Treaux and 86-cm tall Pat Bilson, and a schoolboy, Matthew de Merrit, who played a scene in which E.T. is drunk.

***Latex rubber,** carefully crafted into custom-made masks and gloves, was used to dramatically age the characters in* Beetlejuice.

Warner Bros/Kobal Collection

MONSTER SOUND

Creating all the sounds of a movie, from footsteps to screaming monsters, is the job of the 'footstepper'. He or she will record the sounds of, say, hitting a steak to simulate punches, crinkling cellophane to simulate flames, or shaking a leather glove to simulate the flapping of a bird's wings. Often animals will be recorded and the sounds distorted to create a monstrous, strange or unearthly effect. King Kong's earth-shattering cry, for example, was simply the sound of a lion's roar – played backwards. A 'mutant' language created in similar fashion for 1932's *Island of Lost Souls* made audiences sick!

Paul Raymonde